Lasers in Surgery and Medicine 21:432–437 (1997)

CO_2 Laser Treatment of Traumatic Pulpal Exposures in Dogs

Petra Wilder-Smith, Dr med dent,[1]* George M. Peavy, DVM,[1]
David Nielsen, DVM,[2] and Anna-Marie Arrastia-Jitosho, DMD[1]

[1]Beckman Laser Institute and Medical Center, University of California, Irvine, CA 92612
[2]Animal Medical Group, Manhattan Beach, CA 90266

Background and Objective: **Successful non-devitalizing treatment of localized pulpal lesions in mature teeth is not ensured using conventional endodontic techniques. The objective of this study was to evaluate CO_2 laser surgical treatment of pulpal exposures in canine patients.**
Study Design/Materials and Methods: **17 permanent teeth with pulpal exposures of ⩽48h duration received localized laser pulp surgery. Laser Parameters: pulse duration: 0.01s, pulse interval: 1.0s, spot size: 0.004cm^2, fluence: 276J/cm^2. Exposures were dressed with CaOH and Glass ionomer. Clinical and radiographic evaluations were performed by one blinded clinician 24 and 52 weeks after treatment.**
Results: **15/17 laser-treated teeth assessed over ⩾1 year post-treatment remained clinically and radiographically healthy.**
Conclusion: **These results demonstrate the feasibility of using the CO_2 laser for localized pulp surgery. Further studies must optimize laser parameters and identify the range of clinical pathologies which can be treated using this modality. Lasers Surg. Med. 21:432–437, 1997.** © 1997 Wiley-Liss, Inc.

Key words: **pulpotomy; CO_2 laser; pulp surgery; dogs; root canal treatment**

INTRODUCTION

When dental decay or traumatic damage in teeth are advanced to the dental pulp, effective treatment after removal of the decayed enamel and dentine must fulfill the following requirements: removal of infected pulpal tissue with minimal damage to underlying healthy pulp tissue; hemostasis; elimination of bacterial contamination in the affected area; stimulation of reparative dentine formation over the pulp wound. At the moment, treatment options in humans and in veterinary patients are limited. They include:

(1) Formocresol pulpotomy, usually in primary teeth, involving amputation of the infected pulp portion, then mummification of the remaining pulp with formocresol. This modality is still widely used in primary teeth, despite the demonstrated irritancy, mutagenicity and toxicity of this agent [1,2]. The results obtained with this technique are unpredictable, and include strong tissue irritation and dental ankylosis. Other agents including ferrous sulfate and glutaraldehyde are currently under investigation for use in conjunction with pulpotomy procedures [2].

(2) In immature permanent teeth in humans, endodontic treatment of choice comprises pulpotomy and subsequent dressing with calcium hydroxide. Inter-

Contract grant sponsor: DOE; Contract grant numbers: DE903–91ER61227, ONR N00014–90–0–0029; Contract grant sponsor: NIH; Contract grant number: RRO1192; Contract grant sponsor: Loma Linda University, Edna P. Jacobsen Charitable Trust for Animals Inc.

*Correspondence to: Dr. Petra Wilder-Smith, Director of Dentistry, Beckman Laser Institute and Medical Center, University of California, Irvine, CA 92612. E-mail: pwsmith@bli.uci.edu

Accepted 20 May 1997

nal resorption may occur after this type of therapy [3]. Moreover, long-term survival of teeth treated in this fashion is not assured and the main goal of this therapy is to permit complete root development prior to subsequent devitalization and root canal treatment.

(3) Where the pulpal exposure is pinpoint, direct or indirect pulp capping may be performed. However, a small percentage of cases is deemed suitable for this type of conservative approach and frequent problems obtaining hemostasis can seriously jeopardize the outcome of this treatment option. Success rates for pulp capping procedures, whether direct or indirect, are unpredictable and range from 44–97% [4].

(4) Devitalization and endodontic treatment. Pulpal extirpation and root canal treatment are performed if pulp capping procedures are not indicated. Disadvantages of this procedure include discomfort and prolonged treatment duration of endodontic therapy, increased danger of tooth fracture, poor aesthetics, financial cost. Success rates of 78–90% have been cited for this treatment form, depending on factors such as the pathologies treated, tooth anatomy, and follow-up duration [5,6].

Thus, both in primary and in permanent teeth, in humans and in veterinary patients, there exists a real need for viable alternatives to conventional techniques.

Pulpotomy is defined as the surgical removal of part of the coronal pulp in an attempt to maintain the health of the remaining pulp [7]. It is widely accepted that crucial requirements for a successful pulpotomy include minimal trauma and hemorrhage control [8,9]. The CO_2 laser became available over 30 years ago and has found widespread application in soft tissue surgery. It emits an infrared beam at a wavelength of 10.6 μm which is readily absorbed by the water in soft tissue [10]. Thus tissue penetration of the laser beam is minimal and laser effects remain superficial and direct to the impact area. The CO_2 laser as a surgical tool has several desirable characteristics compared with other lasers and with conventional surgical techniques. It has the ability to perform precise, bloodless soft tissue surgery with minimal disturbance of the surrounding tissues [10,11,12]. The CO_2 laser can be used to sever pulpal tissues while inhibiting hemorrhage. Furthermore, the potential for sterilization has also been demonstrated [12,13]. In addition, bacterial contamination can be avoided during surgery, a factor believed to cause internal resorption during calcium hydroxide pulpotomy [8]. In this respect, the CO_2 laser has much to offer to improve the success rate of pulpotomies.

The objective of this study was to determine the effectiveness of CO_2 laser surgery for the removal of diseased pulp tissues in dog's teeth. Radiographic and clinical evaluation were performed over 12 months after treatment. As pulpal events in dogs and in humans are comparable in many respects, this study may be regarded both as an investigation into potential new veterinary treatment options, and as a preliminary investigation into possibilities for future human treatment modalities.

MATERIALS AND METHODS

The protocol for this study was reviewed and approved by the appropriate animal care committees.

Animal Inclusion Criteria

Either male or female normal cephalic dogs, weighing between 25–75 lbs. were chosen. The dogs were in overall good health, were "conditioned" i.e. dewormed, and had received all necessary immunizations including those against rabies, distemper, and infectious canine hepatitis. An inhouse blood and chemistry panel was performed within seven days of their initial office visit. Urinalysis was performed when liver or kidney test results were abnormal and when clinical signs and symptoms indicated the need. Stool examinations were required if the patient presented with gastro-intestinal problems. Special attention was given to behavioral patterns of dogs including chewing habits, as well as dietary habits. Medically compromised patients such as those with concurrent heart, liver, renal disease, or malignant neoplasia were excluded from this study.

Tooth Selection

The criteria for tooth selection were based on clinical and radiographic examinations.

Clinical criteria. The tooth to be treated should have experienced a recent pulpal exposure, with the pulp exposed to the oral fluids for $\leq$48 hours. The tooth involved had to be restor-

able with the said exposure supra or equi-gingival. Teeth were allocated to one of the following 4 sub-groups, depending on the exposure size: <1 mm diameter; 1 to <3 mm diameter; 3 to <5 mm diameter; ≥5mm diameter. A tooth with any fracture line involving the root portion of the tooth was excluded from the study. Excessive hemorrhage from a pulp exposure indicating long standing inflammation was cause for exclusion from the study. The general oral condition of the patient had to be healthy. Causes for exclusion included: severe gingivitis; periapical infections, including draining fistulas, periapical redness, and swelling; periodontal disease, with pockets measuring over 6mm, or with tooth mobility exceeding 2mm; very deep and very large carious lesions; crowned restorations.

Radiographic criteria. The tooth to be treated should present normal radiographic features. The lamina dura should be intact and continuous. The periapical tissue and surrounding bone should also be normal. Pulp stones obliterating the pulp chamber should not be present in the radiographs. The radiographic pulp size should be at least a third of the mesio-distal, bucco-lingual, and cervico-occlusal height of the tooth. Radiographic indications of chronic pulpitis/pulpal inflammation including the presence of periapical bone deposition, hypercementosis, or incipient chronic apical periodontitis on any teeth were cause for exclusion from the study.

At this time, 17 teeth have been treated and followed up over a period of 1 year or more.

Laser Treatment

Laser parameters were selected from preliminary studies which identified parameter configurations with minimal thermal impact in adjacent pulpal tissues [14]. Pulpal exposures were treated at the following parameters using a CO_2 laser emitting at 10.6μm (Premier Laser Systems, Irvine, CA):

spot size: 0.004cm^2
pulse interval: 1.0s
pulse duration: 0.01s
power: 4W
irradiation duration: usually 3 bursts of approximately 0.5s each

Surgical Procedure

After obtaining a complete and comprehensive medical and dental history of the patients, the patient was pre-anesthetized using an oral administration of Propofol (2–4 mg/lb.) with maintenance on isoflurane and oxygen. Cardiac and respiratory functions were constantly monitored. After the onset of sedation, radiographic exposures were taken of the tooth to be treated. Conventional straight-line access to the pulp, using burs #2, 701, 703, 253 was prepared using a high speed dental handpiece. All carious dentine was removed with a #2,3 spoon excavator. Sterile saline solution was used to debride the access cavity and bleeding controlled when appropriate with sterilized cotton pledgets. The exposure site was then irradiated, dressed with calcium hydroxide paste, and restored with Glass Ionomer Cement. Calcium hydroxide paste was used despite it's known effects on pulpal healing, because it's use represents standard current technique, allowing a comparison with the outcome of conventional pulp capping-like procedures. Post-operative radiographs were taken as described above, and the patient's recovery closely monitored.

Treatment Evaluation

Clinical evaluations including visual and tactile tests to diagnose the presence or absence of periapical pathologies, including abscess formation, pus drainage, or a fistulous tract, were performed by one blinded, standardized operator 24 and 52 weeks post treatment. Clinical response was scored as follows:

−1 Periapical palpation suggests development of a pathosis. A pathology is clinically present when there is abscess formation, pus drainage, or a fistulous tract.
0 Unchanged from the baseline. Suggests a stable condition.

Radiographic evaluations were conducted by the same clinician to determine changes in the integrity of the lamina dura as well as the development of areas of rarefaction.

The radiographic evaluation was scored separately:

−1 Break in the continuity of the lamina dura; development of a periapical pathosis indicated by an area of rarefaction on the radiograph.
0 Unchanged from the baseline. Suggests a stable condition.

Statistical Evaluation

This paper presents preliminary results of an ongoing study, which also includes a "control"

group treated identically to the "laser" group except for the use of a high-speed diamond bur for removal of compromised pulpal tissues. A formal statistical analysis of the preliminary findings presented here is not appropriate at this stage.

RESULTS

Clinical Impressions

During laser treatment, hemostasis was not immediate in 5/17 teeth treated, requiring application of pressure using sterile cotton wool pledgets to achieve full cessation of bleeding. In the 5 teeth thus treated, 2 evidenced an exposure 1–3mm in size, 3 evidenced an exposure 3–5mm in size. The laser procedure itself was very rapid, and added only a few seconds to total treatment duration.

Clinical Results

1 year after treatment, 15/17 treated teeth appeared clinically healthy according to the criteria listed above. The 2 teeth which developed periapical swellings had both experienced loss of their restoration within a few months of treatment. Both of these teeth had experienced difficulties with hemostasis during their laser pulp treatment. 1 tooth evidenced an exposure 1–3mm in size, the other tooth evidenced an exposure 3–5mm in size.

Radiographic Results

1 year after treatment, 15/17 treated teeth appeared radiographically healthy according to the criteria listed above (Fig. 1a,b). The 2 teeth which developed periapical radiolucencies had both experienced loss of their restoration within a few months of treatment (Fig. 2). These were the same 2 teeth in which treatment had also failed as judged by clinical criteria.

DISCUSSION

In dogs, treatment of exposed pulps remains problematic, the outcome of pulpotomy procedures is variable, at best, and root canal treatments are expensive, demanding and also less than predictable in their outcome. Tooth extraction is undesirable for a wide range of reasons. Similar arguments apply to current pulpal treatment modalities in humans.

The laser parameters used in this study were primarily dictated by thermal considerations.

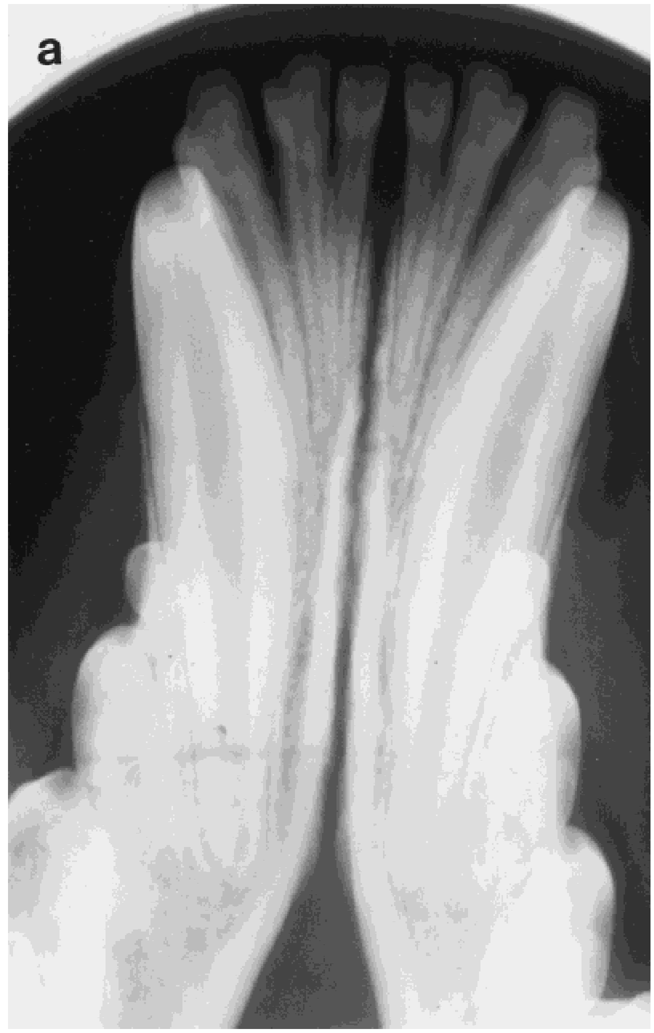

Fig. 1a. Radiograph of dog "C" directly after laser pulpotomy treatment.

From the experience gained in this investigation, it has become apparent that careful modification of the laser parameters used is necessary to improve hemostatic effect whilst minimizing thermal implications in collateral tissues.

The prerequisites for successful pulpotomy are well met, theoretically, by the surgical properties of CO_2 lasers: atraumatic removal of compromised pulpal tissues [15], hemostasis and minimal clot formation [8,9], and bacterial elimination [2]. These preconditions can be achieved using the CO_2 laser at appropriate parameters. Because the laser handpiece is used in the noncontact mode, it has no mechanical contact with the tissue, and trauma to the residual tissues is avoided [16,17]. Laser irradiation at this wavelength consistently achieves rapid and effective hemostasis and minimal clot formation in blood

Fig. 1b. Radiograph of dog "C" 1 year after laser pulpotomy treatment, showing no changes in healthy periapical status.

Fig. 2. Radiograph of dog "G" 1 year after laser pulpotomy treatment, showing periapical rarefaction indicative of periapical pathology.

vessels up to 0.5mm in diameter [18,19]. Many authors report effective wound sterilization during soft tissue surgery with this laser [20,13]. CO_2 laser irradiation has been shown to achieve sterilization and hemostasis in an open pulp wound [13]. Many authors associate CO_2 laser soft tissue surgery with reduced swelling, edema and pain [16,18–20]. Pulpal exposure to CO_2 laser irradiation has been linked with reparative dentine formation [13]. In a study investigating tissue response following periapical surgery with the CO_2 laser, no adverse effects on soft tissue healing were identified [21]. Thus, the CO_2 laser is able to fulfill the prerequisites for successful localized laser pulp surgery. The preliminary results presented in this paper do indeed demonstrate a great potential for localized pulp surgery using this device. Interestingly, the 2 teeth in which treatment failed both lost their restorations early, so that at this time it remains unclear whether this failure was due to the laser pulp treatment, or to pulpal re-infection.

In conclusion, these preliminary results demonstrate the feasibility of using the CO_2 laser for localized laser pulp surgery in dogs. Further studies are required to optimize the laser configuration and to identify the range of clinical pathologies which can be treated using this modality.

ACKNOWLEDGMENTS

This study was supported by: DOE Grant DE903–91ER 61227, ONR N00014–90–0–0029, NIH RRO1192, seed grant funding from Loma Linda University, the Edna P. Jacobsen Charitable Trust for Animals, Inc.

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